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ABSTRACT

The number of women in the workforce has increased dramatically. However, the number of high school females enrolled in physical science classes remains low. To aid in ensuring that females succeed in the physical sciences, a symposium was held. This document highlights the events of the aforementioned symposium. The "Girls and the Physical Sciences Symposium" had three distinct components. Opened by keynote speeches from two leading researchers and scholars, Shelia Tobias and Pat Campbell, Part 1 placed the teaching of physical science into a national context. These introductory comments helped set the stage for the second part of the document, a series of workshop presentations. Each of these sessions began with a set of findings or experiences illuminating the practice of physical science. Participants ultimately joined in discussions on one of the selected topics. These conversations contributed to the third phase of the conference, teacher exchanges, and led to a host of practical suggestions for classroom reform. The document also includes additional references related to women in the physical sciences and classroom assessment of women. (ZWH)

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Girls and the Physical Sciences

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Symposium Highlights

March 12, 1993

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Girls and the Physical Sciences

A Symposium held at
The Science and Technology Center, Tufts University
March 12, 1993

The Symposium Organizers

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The Symposium Sponsors

THE WRIGHT CENTER FOR INNOVATIVE SCIENCE EDUCATION at Tufts University is dedicated to the creation and dissemination of novel teaching techniques and resources for pre-college teachers. Through its fellowships, workshops, seminars, and a variety of public outreach activities, the center provides leadership in the training and retraining of science teachers to use innovative methods to stimulate young intellects.

Director: Dr. Eric J. Chaisson

THE NATIONAL COALITION OF GIRLS' SCHOOLS is an organization of sixty-seven boarding and day, public and private schools from across the United States. While differing in various ways, Coalition members share a belief in and a commitment to the values and advantages of an all-girls school. To this end, the organization has collected research on gender issues; hosted national forums for leading girls' and women's groups; sponsored the *Math and Science for Girls* and *Girls and the Physical Sciences* symposia; and created a series of publications.

Executive Directors: Meg Milne Moulton and Whitney Ransome

Today's Learners, Tomorrow's Leaders

Why a Conference on Girls and the Physical Sciences?

A MAJORITY OF JOB OPPORTUNITIES in the twenty-first century will be rooted in science and technology. America will therefore need its citizens to be scientifically literate if they are to keep up with an increasingly complex and technological society. Today's national statistics are far from encouraging. By the year 2010, over 50% of the workforce will be female, but among current high school students, only 30% of the students in chemistry and 15% in physics are girls. The climate for young women in these subjects will need to change if our country is to draw upon all its resources.

Like many good ideas, the concept for convening a conference on *Girls and the Physical Sciences* was the inspiration of a classroom teacher. Ileana Jones, physics and middle school science instructor at The Winsor School (MA), used her year as a fellow at Tufts University's Dudley Wright Center for Innovation in Science Education to create a one-day program that would highlight the challenges and opportunities for girls in the physical sciences.

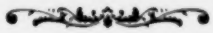
Early in the planning stages, Ms. Jones called on the National Coalition of Girls' Schools; Ann Pollina of Westover School; Katy Schmitt of Concord Academy; and Eric Chaisson, Director of the Dudley Wright Center, to join with her in developing the symposium. Together they share an abiding interest and concern for the science education of girls. Compelled by the dearth of females pursuing courses and careers in the physical sciences, the planning group called on writers, researchers and practitioners to identify the ways and means to retain and increase participation of this under-represented group.

Girls can and will succeed in the physical sciences when teachers use classroom strategies that are particularly effective for engaging them. Conference organizers gathered together close to one hundred educators interested in the reform of science teaching. Many brought with them lessons learned in all-girls schools that, if adopted more widely, could help diminish the inequities in science education and employment.

In their speeches and workshops, conference presenters generated an array of recommendations for changing the way in which the physical sciences are taught. This booklet seeks to share with a larger audience highlights and major findings from that exciting day in March, 1993. Our special thanks to the speakers and educators who came from all over the country. Their debates and discussions have helped set a new course for girls in the physical sciences.

• WHITNEY RANSOME AND MEG MILNE MOULTON, *EXECUTIVE DIRECTORS* •
THE NATIONAL COALITION OF GIRLS' SCHOOLS • 228 MAIN STREET, CONCORD, MASSACHUSETTS 01742

Introduction



THE *GIRLS AND THE PHYSICAL SCIENCES SYMPOSIUM* had three distinct components. Opened by keynote speeches from two leading researchers and scholars, Sheila Tobias and Pat Cambell, Part One placed the teaching of physical science into a national context. These introductory comments helped set the stage for the second set of offerings, a series of workshop presentations. Each of these sessions began with a set of findings or experiences illuminating the practice of physical science. Participants ultimately joined in discussions on one of the selected topics. These conversations contributed to the third phase of the conference, teacher exchanges, and led to a host of practical suggestions for classroom reform. What follows is an overview of those various comments and conversations.

• PART ONE •

Experts Speak About The Myths and Messages of Physical Science

Mainstreaming Women In Science: The Next Steps

Sheila Tobias

Visiting Scholar, University of Arizona, Author of "Overcoming Math Anxiety" "They're Not Dumb, They're Different: Stalking the Second Tier" and "Breaking the Science Barrier"

Cultural Issues Keep Girls Out Of Physical Science

RECRUITMENT AND RETENTION in the physical sciences is a problem for the nation as a whole. The issues confronting girls as well as other underrepresented groups revolve around how physical science is currently taught and practiced. Ms. Tobias urged educators to examine the anthropology of science, to think of scientists like a tribe, and consider the operative assumptions which determine the mythology about who does physical science. Three questions warrant a second look:

- Who will do science?
- When will interest in science manifest itself?
- How is science practiced?

Meta-stereotypes

Practicing physical scientists harbor "meta-stereotypes" in their answers to these questions. Their prevailing attitudes are damaging to girls and non-white males and preclude them from the pursuit of science. What are the operative attitudes?

#1: Who Will do Science?—The Elite

Scientists are a self-selected elite, who are smart in special ways that are innate. One can't work hard and learn science over time. This assumes one has to have it early on. It's as if people are born with a "magic quality" which allows them to shine in the sciences. This is unlike Francis Bacon's description of science which "enables ordinary people to do extraordinary things." If we allow the definitions of today's practitioners, ordinary people are going to be absent from the recruitment pool.

#2: When Will Interest in Science Manifest Itself?—It's Predestined

A small group of people are predestined to be scientists and know this early in their lives, as if to suggest there were a science gene. They are the ones whose first toy had to be a chemistry set. This predisposition assumes that teachers are unnecessary, motivation is a moot point, and late-bloomers in science are non-existent.

#3: How Is Science Practiced?—By The Single-Minded

A single-minded, unwavering commitment is needed to be a scientist. Multiple interests are anathema to a physical scientist's life; outside passions are suspect. Any complementary or contrapuntal interest which could add to the enjoyment of a physical science study is not thought of as germane.

"As a current scientist, I came to the profession one way and that is the only way it can be done," goes the litany. Varying styles and models of doing science are not acceptable. Anyone who doesn't fit a predetermined mold can't possibly be a scientist. There are men and women, and then there are scientists.

Countering Meta-stereotypes: Strategies for Reform

How can the culture of science be changed to include more women? Several simple adjustments in attitude and approach will help to make a difference:

- Demystify the profession and its view of itself.
- Make way for a new group of students ... the "high verbals." Most women first demonstrate verbal skills — this, too, is important to science. Motivation and high verbal scores can lead to high physical science scores. The idea that

people will be good at just one type of knowledge (i.e science, math or humanities) is unfair to science and to students. It minimizes the importance and advantages of high verbal aptitude in science.

- Re-evaluate the significance of an early interest in science. Motivating students with a delayed interest is important in recruiting scientists.
- Provide role models for girls to emulate and to stimulate their motivations, models of young women scientists who have survived college or are "living the life of the mind." Allow for a fourteen-year window of personal identification—women in their twenties are the most viable role models for young girls.
- Make persistence and hard work the success variable in science, not just predetermined talent.
- Redefine a life in science. Foster the sense of mystery and meaning in science with which women identify. Validate the "Eureka" moments.

Practicality and Passion: Gender Issues in Science

Dr. Patricia Campbell

Former Associate Professor of Research, Measurement, Statistics, Georgia State University
Co-Author AAUW Report, "How Schools Shortchange Girls"

A Status Report on Girls in Math and Science

The Good News is in Math:

- In the past eighteen years, gender differences in math areas have decreased by over 50%.
- Gender differences in mathematics achievement are now small, with no overall differences in math concepts, slight differences favoring girls and women in computation, and slight differences favoring boys and men in problem-solving.
- In high school, approximately the same numbers of girls and boys take algebra, geometry, and trigonometry, while significantly more boys than girls take calculus.

The Bad News is in Science:

- A lag in the performance of girls and significant increases in the performance of boys has increased gender differences in science achievement. The areas of largest male advantage are physics, chemistry, earth science, and space sciences.
- While approximately the same numbers of girls and boys take biology and first-year chemistry, significantly more boys than girls take second-year chemistry and physics in high school.

The critical point is that in both math and science, educational successes have been in areas of practicality, not of passion. Girls (and even many boys) are not excited about math and science.

- Less than 4% of girls and almost 18% of boys taking the SATs planned to major in engineering in college, while almost no students planned to major in math (girls = .05%, boys = .06%).
- Among girls and boys taking calculus and physics in high school in one state, more than 60% of the boys and less than 20% of the girls were planning careers in math, science, or engineering.

The Problem is Science, Not Girls!

The underrepresentation of girls in these areas has been seen primarily as a "girl problem." This assumes that the difficulties are caused by girls, by something they do, or more often, by something they lack. To solve a problem defined in this way, one works to change the girls so that they become more compatible with science and mathematics. Most of our efforts up to now have focused on changing

girls: on encouraging girls to use science, like science, and to become the kinds of learners who do well in science.

This definition of the problem and resulting solution minimizes or ignores the role that teachers, educators and society play in who we are, how we learn, and what we learn. As successful change-agents in business have found, changing one component of a system causes short-term but not long-term change. If you change a girl so she "loves science" and put her back into the same environment that caused her to hate science in the first place, no ground has been gained.

Remedies for Reform

There are a number of things that can encourage girls in math and science and that have implications for teaching.

Programs That Work:

- Are considered by the girls to be NOT LIKE SCHOOL and are fun.
- Include a lot of hands-on activities, projects, and opportunities for participation.
- Are much less concerned with increasing cognitive knowledge than with helping girls do new things.
- Are relaxed, with little or no emphasis on individual competition.
- Provide opportunities for girls to speak informally with women and men in math and science and learn about their lives.
- Allow time for questions and limit the teacher-provides-answer format.
- Include parents who mentor and nurture their daughters' science abilities, interests, and talents.

• PART TWO •

The Work and Recommendations of Physical Science Practitioners: A Series of Workshops

Introduction

Symposium participants joined with physical science experts in conversations and debate on four subjects that affect interest and performance in the physical sciences:

- The National Debate on Assessment: Pilot Alternative Models
- Changing the Image of What a Scientist Is and Does
- Successful Models, Intervention and Presentation Methodolgies
- Student Experiences—Leaders in Training

In the workshop summaries which follow, key issues are supplemented by related suggestions and strategies for improving the involvement of girls in the physical sciences.

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Workshop #1

The National Debate on Assessment: Implications for Girls and the Physical Sciences

Speaker: Dr. Maryellen C. Harmon

Senior Research Associate, Center for the Study of Testing, Evaluation, and Educational Policy, Boston College

Facilitator: Ann Pollina

Dean of the Faculty and Head of the Mathematics Department, Westover School

Presentation Summary

THE ASSESSMENT SESSION BEGAN with an overview of a recent publication by Dr. Maryellen Harmon and her colleagues at Boston College, "The Influence of Testing on Teaching Math and Science in Grades 4-12." The research behind the paper proceeds from the belief that standardized tests can inhibit or prevent reform in teaching.

The Structure of Tests Today

Much of what we use in standardized and text-embedded tests is inadequate to support the science-education reform movement. A recent study of the six major standardized tests in use across the United States and the publisher-supplied tests from the four textbook series (which hold the top four positions of market share in elementary and secondary science) revealed serious weaknesses in existing tests. For example, content coverage of the tests is uneven, with 30% of all items across all grades measuring life sciences and less than 3% measuring each of the physical sciences: heat, light, electricity, sound, or magnetism. In addition, about 80% of the standardized test items and 92% of the text-embedded items measured recall of information—the ability to recognize and name facts and concepts, rather than measuring the ability to explain, compare or contrast, or to identify critical characteristics; i.e. to use higher order thinking skills. Understanding of experimental procedures were measured by only 8% of the standardized test items and 5% of the publisher-supplied items, in spite of the importance of experimentation in doing science. Experimental design and data interpretation represented an even smaller number of items. By its very nature a written test is not suited to determine whether students can actually use scientific procedures, collect data, and then make sense of it. This aspect can only be determined by performance assessment, but data could be provided for interpretation even in the standardized test format.

What all of this means is that the primary content of existing standardized and publisher-supplied tests consists of memorized items, rote recall of facts and concepts, with little reasoning or experimental understanding and almost no problem solving. These existing tests may well be a serious inhibiting factor to the movement for reform in science education since they do not sample procedural knowledge—which is the cornerstone of the current emphasis on hands-on, real-world science—and since they reward memorization rather than conceptual understanding.

Strategies for Change

What then are the alternatives? They may be in written, oral, or performance formats. Multiple choice tests themselves can be improved by removing ambiguities and redesigning the choices so that a test-wise person is not cued to the correct answer without any real conceptual understanding. In addition, coupling a well-written multiple-choice item with a second question: "Why?" or "Explain your choice" quickly reveals whether the student understands the relevant concepts or simply recalls their names.

Other written alternatives include short answer and longer essay questions, concept maps, and portfolios. Concept maps are one way of networking ideas with a list of connectors to show cause-effect and other relationships. Portfolios contain a collection of work across time, carefully selected to show progress, as well as the student's self-selected "best work," revised work, and the student's reflection on her learning about the topic and about her own strengths as a learner of science and areas for further work.

Performance or Practical Assessments

Students actually work with materials to solve problems, and in so doing, they demonstrate their grasp of experimental design, ability to develop hypotheses, use procedures, collect and interpret data, determine implications, and evaluate design, methods, and results—in other words, to "do" science. Performance assessments are evaluated according to predetermined criteria, similar to the way performances of Olympic athletes are judged. They may range from those embedded in the ordinary curriculum to more contrived "circuses" used at the end of term as part of the final examination, and from very simple short tasks to extended problems and projects continuing over days and months.

Embedded Assessments

- A selection is made of lesson material, but instead of the teacher leading the instruction, the lesson is constructed in such a way that the students, usually working in groups, perform the experiments, discover patterns, and arrive at concepts or working hypotheses (which the teacher will later elicit and discuss with them). During the embedded assessment time, the teacher, after initial directions, becomes invisible—circulating the room to note how students approach tasks, what skills and concepts they use, and what weaknesses or misconceptions appear. It is both an interim assessment and a means to guide future lessons.

Extended Problems

- Extended problems are real-world tasks performed over several days, such as measuring river flow over time, mapping or charting landscapes, or determining the nutritional content of common supermarket brand foods. Projects extend the time even further, and usually require independent question development, research, and presentation.

Circuses

- Circuses, often used at the end of a term, consist of a number of stations arranged around the room, with materials and a question for investigation set up at each, as well as a recording sheet with reflection questions to be answered in the light of the investigation results. For younger children, the tasks may require 5-7 minutes; for high school students, 20-45 minutes.

Other Performance Assessments

- Role plays, simulations, marathons, exhibitions, and even internships are other performance assessment alternatives.

Assessment Caveats

There are two important things to remember. First, whenever assessment is used for high stakes purposes (grades, promotions, or college admission), it should be based on a number of modes, not confined to written or multiple choice forms alone. At least three of the various written and performance forms described above could be included because some students do better in one mode than another, and girls generally do better in essay or performance modes than on multiple choice forms.

Second, no assessment instrument or mode should be considered ready for use until criteria and specific item rubrics have been developed which will enable teachers to determine fairly what is to be considered an excellent, an adequate, or a poor answer for each question. To the extent possible, criteria should be published in advance so that students know what is expected of them and can gradually learn to evaluate themselves. Obviously this does not mean answers to questions should be public knowledge.

Science and the Gender Factor

How does all of this relate to girls and the physical sciences? Dr. Harmon contends, supported by authors like Gilligan and Belenkey, that girls do not typically think in linear, right/wrong categories, but tend to see things in context, to demonstrate great practical intelligence in real-world situations, to look at both sides of a dilemma and try to develop a win-win rather than a win-lose strategy (Gilligan, 1982). Girls synthesize and make connections almost naturally instead of dividing their thinking and knowledge into discrete compartments. But the standardized tests imply that there are absolute right/wrong answers to all questions ("imply" is used since 20% of the items on standardized science tests were in fact ambiguous, with multiple answers, or no "right answer"). They require forced choices, often non-contextualized, and unrelated to any real-world thinking. None of these are congruent with even the little we know of women's ways of knowing. Belenkey makes a strong case for the distortions women experience when they bend their thinking, manner of expression, or behavior to meet the demands of academia and the corporate world. For these demands are not congruent with womens' imaginative and creative ways of problem solving or their empathic ways of relating to others.

Workshop #2

Changing the Image of What A Physical Scientist Is and Does

Speaker: Dr. Adele Wolfson

Associate Professor of Chemistry, Wellesley College

Facilitator: Dr James Bond

Physics Teacher, Foxcroft School

The Image Problems

HOW AND WHY DO YOUNG WOMEN develop certain concepts and images of physical science and physical scientists? The list of stereotypes is an interesting one:

1. Physical science is a male enterprise. It is no wonder that this image persists since most practitioners in the field have been predominantly men.
2. All too often science is considered an intellectual endeavor unsuited for women. However, no scientific evidence supports the idea that there exists a genetic basis for male superiority in mental abilities required to do science.
3. In addition to the usual portrayal of scientists as men, other conventional stereotypes are that scientists: have to be brilliant; have to work alone; can't deal with people; are rigid and analytical rather than creative and open. The significance of these sterotypes is that they discourage the very people we would like to see becoming scientists from entering science. They seem to be particularly discouraging to young women.

The Image Solutions

If in fact these "images" are deterrents for women entering science careers, we need to determine what can be done to alter those images. We need to focus on what it is about science (or how it is taught) that makes girls and women think that they don't want to do it.

1. Encourage students to view themselves as scientists.
2. Provide students at all levels of learning with the opportunity to interact directly with scientists.
3. Have scientists more actively involved in the education process by working with teachers at all grade levels. The idea is not to have scientists take over the teaching of science, but to share their knowledge, enthusiasm, and passion for science.
4. Engage sufficient numbers of scientists in science teaching so that the myths and mistaken impressions promulgated by the stereotypes disappear.
5. Illustrate the variety within the field of physical science. While it is true that science, especially physical sci-

ence, is dominated by men, they comprise a broad spectrum of personalities and intellectual abilities.

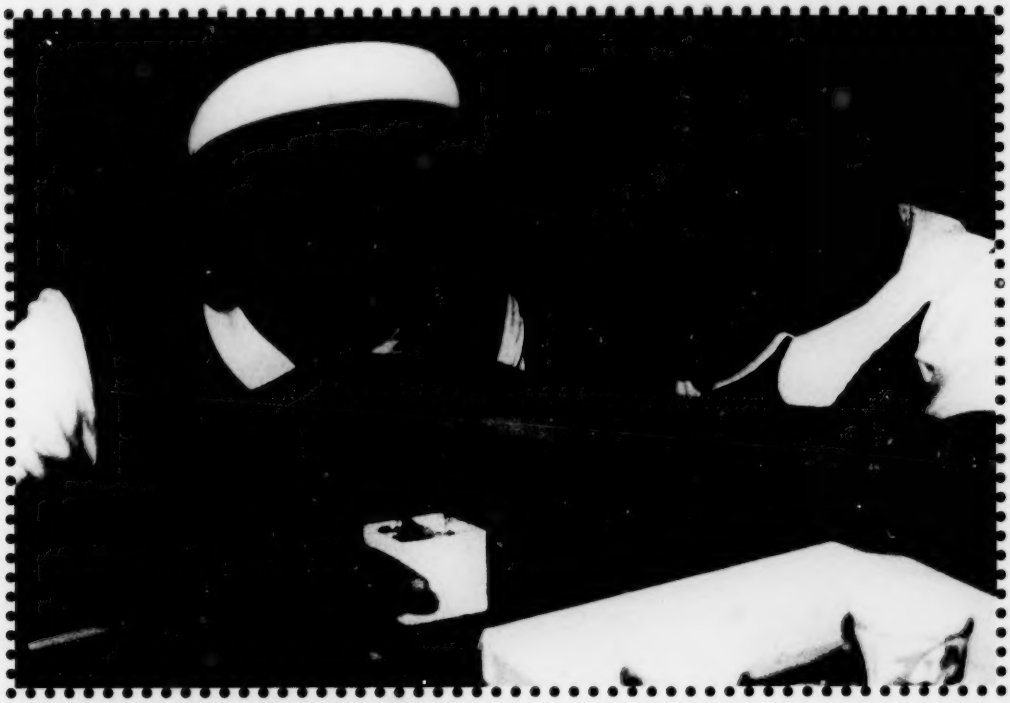
6. Show students physical science workplaces. Seeing scientists —both men and women — at work in laboratories, at computational centers, in engineering and manufacturing facilities where applied science is practiced would help reverse the mistaken beliefs of what scientific work is all about.

7. Create links with outside sources. Schools should form partnerships with corporations and universities, bringing professionals in to the school and taking students out to the organizations.

8. Help students to see their teachers as scientists as well as instructors. The role of classroom teacher is extremely important.

9. Stress the relevance of science to everyday life.

10. Make sure that studens have opportunities for hands-on, discovery-based laboratories and research experiences.



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Workshop #3

Successful Models Intervention and Presentation Methodologies

Speaker: Dr. Jocelyn Spragg

Radcliffe Summer Program in Science and
Division of Medical Sciences, Harvard Medical School

Facilitator: Ileana Jones

Physics and Middle School Teacher, The Winsor School
H. Dudley Wright Fellow, Tufts University

The Radcliffe Summer Program in Science: A Model For Success

DR. JOCELYN SPRAGG opened her session by describing the goals and techniques of the girls' science curriculum she has developed as the course portion of the Radcliffe Summer Program in Science. Eight weeks each summer a group of 30–40 high school students from around the world participate in a special course. They come to the program already interested in science and math and have had biology and either chemistry or physics.

The program includes site visits to see women scientists in their workplace as well as meetings in an informal "career conversation" setting. The students have opportunities to expand their understanding of several science disciplines, to become more self-confident in their ability to excel in academic settings, to learn more about a variety of science and math careers, and to meet women successfully engaged in those careers. The major goal of the Radcliffe program is to better prepare girls for the challenging science curricula they will encounter in college, and to give them the skills necessary to persist in science careers. There are a number of important ways to achieve these objectives:

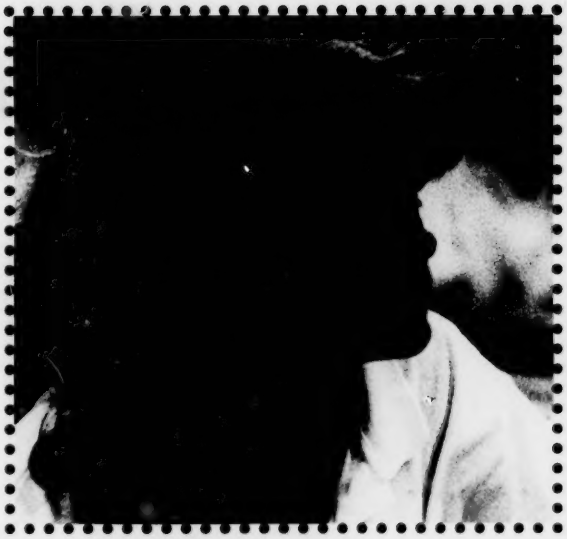
The Radcliffe Goals

- Focus on understanding concepts rather than on memorizing information.
- Have students participate actively in the learning process.
- Allow students to become competent in the laboratory and to understand the operating principles of the equipment that they were using.
- Emphasize the use of quantitative thinking.
- Present mathematics as a language rather than as groups of abstract and (to the student) often meaningless formulas. Think about how equations can be used and manipulated.

- Emphasize the interrelatedness of the natural sciences and the role of math in science.
- Think about science as a process. Think about how we know what we know; that is, think critically about science.
- Think about how scientists think about science.
- Gain some comfort with the concept of uncertainty and probability.

Radcliffe Teaching Strategies

- Divest yourself of the notion that you will teach your students everything you know.
- Understand what main points you want the students to know and how you will help them to accomplish this.
- Realize that they will need frequent external motivators to do the work.
- Plan and analyze the questions you will ask as you prepare lectures.
- Use higher order questions, which focus on understanding the concepts, rather than on memorization. These evoke the students' own experiences, and help them relate the course material to their own lives. Design questions that ask students their opinions.
- Avoid questions that can be answered with a yes or no.
- Ask "What do you see and how do you think it might work" at the start of a lecture demonstration.
- Draw upon one-minute papers. At the beginning of a lecture, tell students you will ask them to answer anonymously three questions at the end of the session: 1. What was the most important point of the lecture? 2. What in that day's lecture was least clear to them? 3. What information do they need to make it clearer?



These brief papers help the students focus on the lecture, help the instructor quickly understand what points need further attention during the next day's meeting, give even the shyest student an opportunity to know that she is being heard, and encourage the students to think actively and analytically about their own learning. In follow-up discussions of their questions, teachers assure the students that confusion is a normal part of learning and that struggling to understand materials is necessary for progress.

Discussion Group and Lab Techniques

Small groups are excellent settings for encouraging active and cooperative participation. Students use sections to review lectures, work on problem sets, and prepare for laboratories by planning their experiments and thinking about some of the guiding questions that are scattered throughout the lab manuals. An effective, nonthreatening technique to encourage students to talk about laboratory plans or problem sets is in groups of two or three. Have one member of each group

report back to the entire section. Even participation in the subgroup counts as participation, and the non-reporter in a pair sometimes feels compelled to correct or expand upon what her partner has said, thus entering into participation in the larger setting.

Lab experiments are intended to be "user friendly," to get students to work cooperatively, to get them involved with understanding why they are doing the experiments, to present students with a series of labs that relate to each other, and to give the students plenty of opportunities to become successful experimenters.

Results of the Radcliffe Program

- Program participants from 1981-1987 earned degrees in math and science at ten times the national rate reported for the years 1966-88.
- Two year follow-ups over the time span from 1981-1990 show an average of 69% of the participants declared science majors in college.
- Anecdotal comments suggest significant improvement in self-confidence and competence as well.

Ultimately what teachers must do is to stretch both their gifted students and their emerging students to new heights of understanding and appreciation for the sciences. Students must move beyond learning for the sake of better test scores on exams such as the AP. Igniting interest and enthusiasm for science, drawing on a commonsense approach to problem solving, overcoming fear of the unknown, and recognizing the value of using what we do know in order to understand new material are key challenges that emerged from work with girls in the Radcliffe Science Program.

Workshop Participants Offer Additional Models for Success

After listening to the major components of the Radcliffe Science Program, workshop members divided into three interest groups to share their own ideas on effective teaching methods. Following is a sampling of their suggestions.

The Middle School Years

Many girls enter science classrooms with fewer "hands-on technological" experiences than boys. This seems to put them at a disadvantage when it comes to laboratory work, particularly in the physical sciences. To help "level the playing field," teachers want to provide alternative opportunities, particularly for their female students in the middle school years. Examples include:

- Design and build a musical instrument when studying waves and sound. Students would also research musical instruments from different cultures before they built their own.
- Explore the technology involved with hair care and ask older generations about hair care technology available during their youth. Tie this in with the study of the Industrial Revolution in history and the reading of Melville in English.
- Build a compound machine by using five simple machines.
- Give students a particular problem and have them design a machine to solve it.
- Use journals and record-keeping to trace physical phenomena such as the moon's phases and observations of shadows.
- Pair girls with other girls in order to avoid boys "taking over," particularly where constructing devices is concerned.

- Alter free choice projects now and then so girls can be gently steered to new areas in which they may be less comfortable. This is often the case when the building phase of a project arrives. With encouragement, girls eventually achieve and enjoy different levels of success in activities where they have had less experience.

Bridging the Gap Between the Middle and High School Years

The gap between girls' and boys' interest in science courses may widen during the critical middle school years as a result of the attempt to teach abstract concepts rather than focus on concrete examples. Boys may have more experience to draw on such as building electric motors, tinkering with tools and building materials, etc. Girls seem to have less physical understanding of how the world works. If boys have fewer misconceptions about physical science, this could account for the fact that boys command presence in the classroom.

Laboratory Strategies

- Use more practical, hands-on activities to supplement what comes with the textbooks. Labs published with texts tend to be sterile.
- Use lab reports as a form of measurement relying on notebooks as well as journals as a means of gathering data.
- Structure labs in an interdisciplinary way. Have students design a research project and submit a group lab report.
- Alter the way in which lab groups are put together. Rearrange the assignment of lab partners on a regular basis so that girls in particular don't get comfortable assuming the role of bystander and recorder.

The High School Years

Take a fresh look at the order of science courses. Some schools offer a full physics course to ninth graders, followed by chemistry and biology. Others teach biology, chemistry, and physics in grade 11, with more advanced courses available senior year. For some schools physical science is the lead-off-course freshman year.

Integrate science with math and with other disciplines, particularly history, social studies, and English (i.e. Scientist as Humanist project, science and English teacher collaboration on writing projects, reading instruction on how to read science books in a different way than novels).

Provide girls (and boys, too!) hints for how to prepare for science courses in college:

- Expect to work hard. Expect to be responsible for your own learning.
- Adapt your learning style. Take advantage of tutors and study counselors. Find out what types of help are available and use them.
- Seek out professors during their office hours. These times are set aside because students are expected to need extra help.
- Be aware that most colleges grade science courses on a curve, and that a very low score may still be a high grade. Realize that many entry level courses are designed to weed out students with less ability and/or determination to succeed.
- Do not expect all A's. College and college grading is usually different from high school. Tell this to the parents, too!!!
- Don't play the helpless female. Assert yourself.
- Ask questions.

Workshop#4
Student Experiences as Leaders in Training

A Discussion With Recent High School Graduates

Facilitator: Dr. Francie Chew

Professor of Biology, Tufts University

Facilitator: Katy Schmitt

Head of the Science Department, Concord Academy
Chemistry and Physics Teacher

Student Panelists:

Sarah Creighton, Bates College; *Jessica Brown,* Smith College;
Audre Van Story, Tufts University; *Elizabeth Battinelli,* Harvard University;
Jennifer Lipson, Harvard University; *Claudine Madras,* Harvard University

Presentation Summary

SIX COLLEGE STUDENTS, GRADUATES from both public and private schools, provided their individual narratives as counterpoint to national figures and trends. Each of them went off to college with the intention of majoring in science. They stressed that college can be a culture shock where young women get silenced in ways they weren't in high school. Panelists provided a series of observations and recommendations that could be helpful for students and teachers seeking to minimize the differences between high school and college science.

What Helped Make the Difference?

- Teachers who made science come alive.
- An all-girls school or women's college where teachers pushed, directed, and knew how to reach the quieter students.
- Family support.
- Female mentors who sought out students.

What Were Some Disappointments?

- The narrow focus of science. Several students really wanted (and in one instance found) ways to combine broader interests, love of the humanities, a different, more general, major while pursuing their core passion for science or math.
- The surprise on the part of female peers when a science major was indicated.

What Were Some of the Benefits?

- Breaking stereotypes can be empowering.
- Analytical tools can be transferred to any number of problem-solving situations in real life or in other academic disciplines.

- As a woman in science you can help reform the way the discipline is viewed, have more lattitude than male peers.

What Are Some of the Strategies That Could Help Others?

- Tinker early on and often.
- Make the abstract concrete and capable of being visualized.
- Emphasize the importance of scientific toys for girls.
- Pay attention to the social context and to bias in science.
- Make the classroom a safe place to make public mistakes.
- Motivate interest through mathematical or scientific aspects of current events.
- Encourage students to find a mentor who will make a difference.
- Teach students to persevere when the going gets tough—to ask the questions, get heard, be aggressive and not worry about feeling pushy... these are the only ways one will survive.

A Final Note

In closing the symposium, Ileana Jones, the principal conference organizer, had an important message to give all participants and the public at large.

"Reforms in science education are a must in order to attract and retain more girls and women to these disciplines. Women need to be a more equitable part of the 5% within this nation's population who are scientists and engineers. But what about the other 95%? In today's increasingly complex and technological society, we need *all* our citizens to be scientifically literate. The themes and teaching strategies recommended during today's discussions can help serve all students. It is imperative for those of us in education to foster greater participation in the sciences. Our nation's success depends on it."

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